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PROCUREMENT SECTION
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COTTON FIBER PROPERTIES
and
TEXTILE PROCESSING RESEARCH
at the
SOUTHERN REGIONAL RESEARCH LABORATORY

Southern Marketing and Nutrition Research Division

Agricultural Research Service

U.S. Department of Agriculture

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at the

SOUTHERN REGIONAL RESEARCH LABORATORY ^{1/}

by

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INTRODUCTION

Utilization research by the U.S. Department of Agriculture uses the resources of science and technology to develop new and improved products from the agricultural crops of the Nation. The Southern Marketing and Nutrition Research Division, better known as the Southern Regional Research Laboratory (SRRL), conducts research on cotton, cottonseed, peanuts, sweet potatoes, citrus, and other farm products grown in the southern part of the United States.

Established by Act of Congress in 1938 and staffed on a small scale in 1941, SRRL has grown to its present total of about 540 employees. Of these, 470 are in New Orleans and the others are at field stations in Florida, North Carolina, and Texas.

Producers of industrial goods and raw materials have conducted utilization research for many years. Their efforts have paid big dividends, notably in the chemical-process industries that use mineral raw materials — petroleum, coal, and natural gas. Some of the new man-made products now compete in markets once held exclusively by farm products. For example, synthetic fibers have captured many of the markets for cotton because they offer properties not found in cotton or because they are priced at levels that discourage competition from cotton.

Fortunately, the properties that nature imparts to cotton can be changed and improved through research. Creating new uses and wider markets for cotton requires scientists of many kinds — chemists, physicists, engineers, fiber technologists, processing technologists — and demands close teamwork because the problems cut across scientific lines. Furthermore, it calls for the coordination of utilization research with farming and marketing research. This requires close cooperation among government, private, and industrial organizations.

To increase the market for cotton means that the consumer market must be enlarged. Therefore, SRRL research has concentrated on: (1) Deriving basic information that will enable the textile industry to use more effectively the properties of cotton in producing high-quality products; (2) developing new and improved consumer products from cotton; and (3) developing textile processes and equipment to produce cotton products at lower costs.

FIBER PROPERTY RESEARCH

Cotton fibers are the structural elements used to form yarns and fabrics. The physical and mechanical properties of the fibers determine the physical and aesthetic properties and ultimately the function of cotton textile products. The relationships of cotton production and ginning variables, fiber properties, and textile processing variables are shown in figure 1. A change in any of the conditions affects the final product.

Some of the findings about the more important fiber properties are presented in this report.

Fiber Length

A single measure of length, known as classer's length or staple length, has long been used as the best criterion of cotton's spinning value. Fiber length is the principal determinant of yarn strength and of the finest yarn size into which a cotton can be spun (1). ^{3/} The influence of length on yarn quality is appreciable. However, it is also well known that cottons with the same classer's length may have different fiber length distributions, with some cottons having more short fibers than others. Short fibers are defined here as those that are less than three-eighth inch long.

^{1/} Presented at the morning session of The Textile Machinery Society of Japan Symposium, Osaka, Japan, July 15, 1970.

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^{3/} Underscored numbers in parentheses refer to Literature Cited at end of the publication.

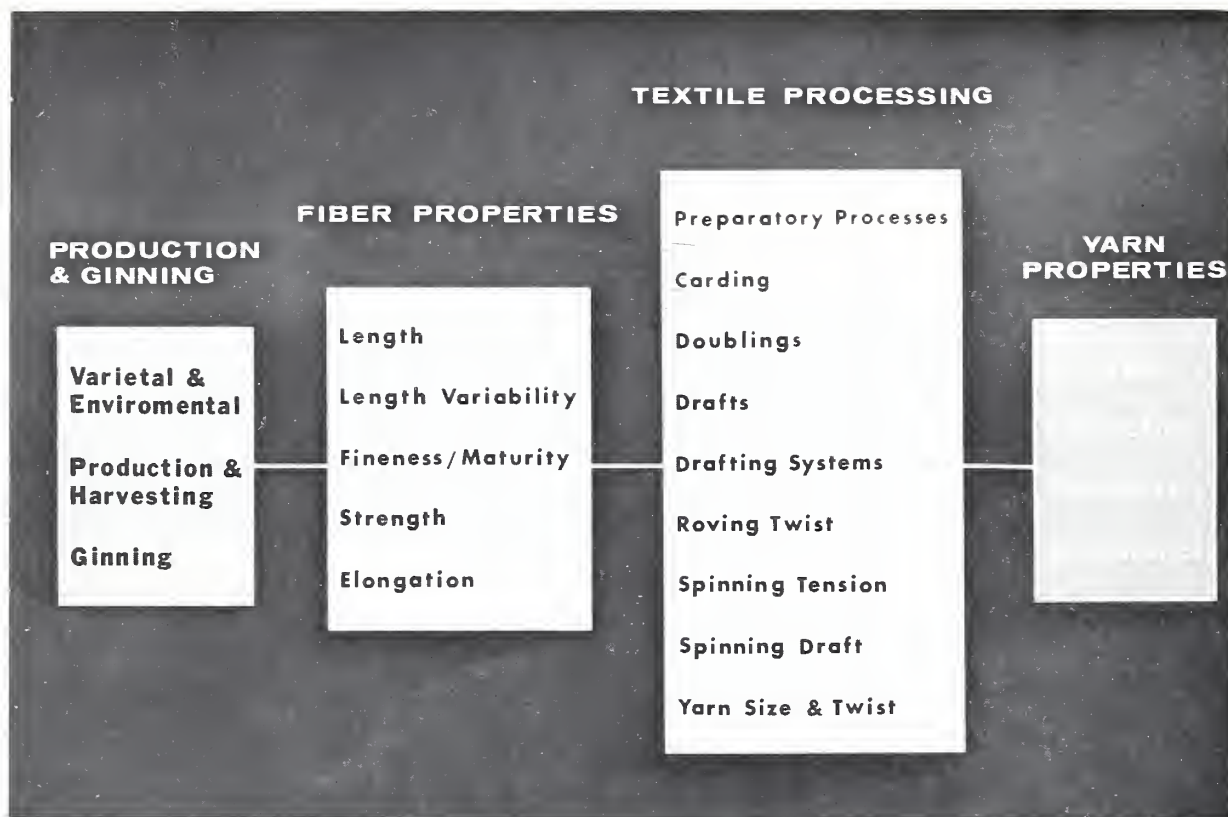


Figure 1. Factors affecting yarn properties.

The importance of fiber-length distribution has been delineated by a series of investigations (13, 27, 29, 30). The findings reveal that increases in short fiber degrade yarn strength and appearance (table 1).

Short fiber content also has a significant effect on ends down in spinning (fig. 2), with 10 percent short fiber content being about the maximum acceptable for efficient mill processing.

Table 1. — Effect of short-fiber content on the quality of yarn

%under 3/8 inch	30/1 warp yarn (20 tex)			40/1 filling yarn (15 tex)		
	Skein strength		Appearance	Skein strength		Appearance
	<u>CSP</u>	<u>%CV</u>	<u>Grade</u>	<u>CSP</u>	<u>%CV</u>	<u>Grade</u>
5	2,668	3.86	B+	2,388	4.90	B
8	2,378	4.52	B-	2,132	4.94	C+
13	2,014	4.91	D+	(^{1/})	(^{1/})	(^{1/})

^{1/} Would not spin because of excessive end breakage.

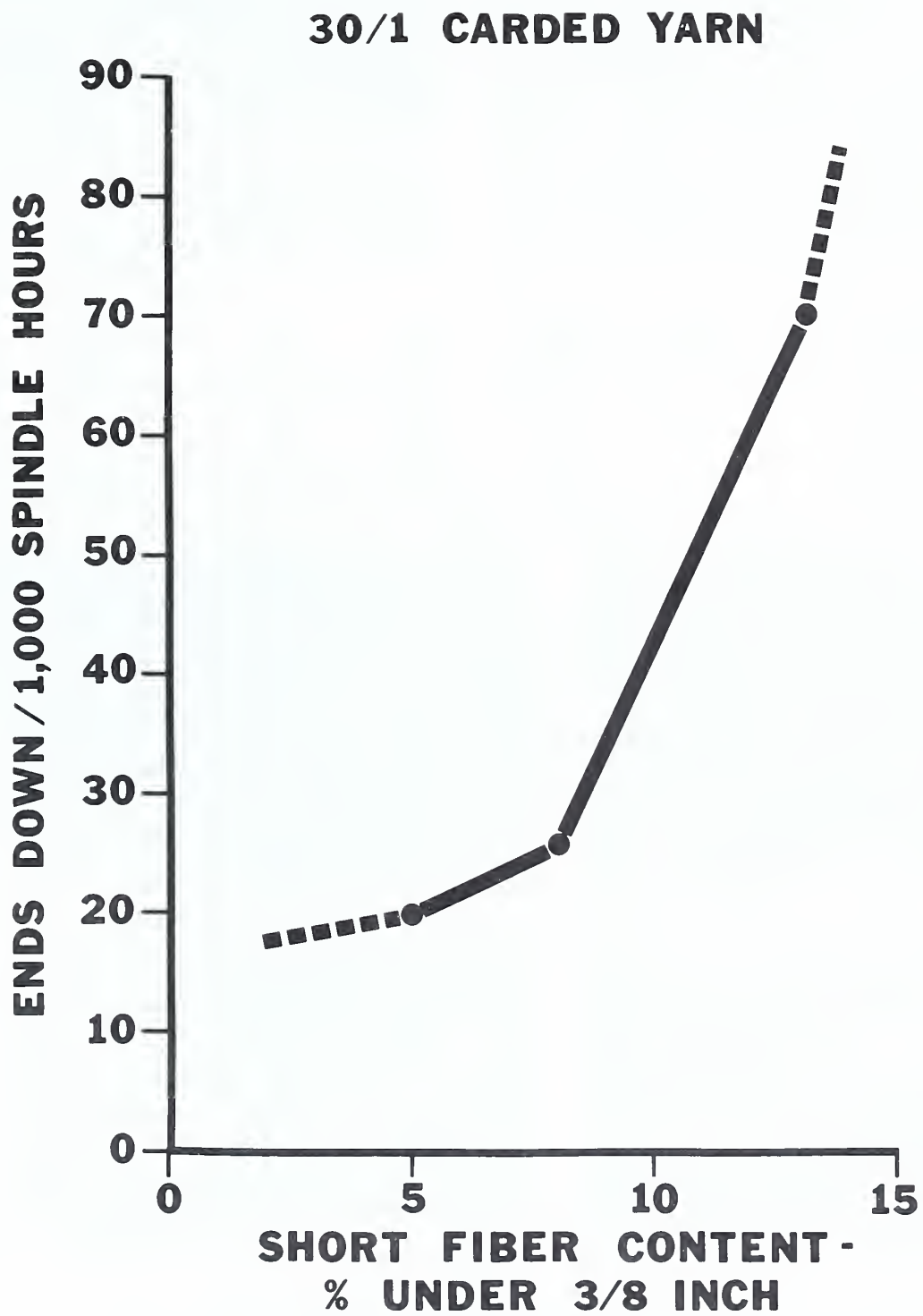


Figure 2. Effect of short fiber content on spinning performance.

Fabric properties are similarly affected by changes in fiber length distribution (31). For example, with additional short fiber content, an 80 × 80 printcloth decreases in tensile and tearing strength and flex abrasion resistance (table 2).

Table 2. — Effect of short fiber content on grey 80 × 80 printcloth

Property	5% ^{1/} warp		8 ^{1/} warp		13% ^{1/} warp	
	5% fill	8% fill	5% fill	8% fill	5% fill	8% fill
Weight-oz./yd.--	3.73	3.75	3.80	3.81	3.79	3.76
Tensile Strength						
Warp--pounds--	59.6	60.2	54.5	53.2	50.2	50.8
Filling--pounds--	47.4	43.7	46.1	43.5	48.0	44.6
Elmendorf Tearing Strength:						
Warp--grams--	1637	1608	1412	1429	1266	1208
Filling--grams--	892	792	875	792	838	771
Flex Abrasion:						
Warp--cycles--	1520	1410	1280	1320	1220	1230
Filling--cycles--	1370	1210	1180	970	1240	1110

^{1/} Percentage of fibers less than three-eighth inch in length

Fiber Finess

Usually expressed in the United States in terms of Micronaire reading, cotton fiber fineness has the most influence of any property on yarn appearance. All other conditions being equal, the finer the fiber, the stronger and more uniform the yarn, because a larger number of fibers are present in the yarn. The contribution of Micronaire reading to yarn strength is generally less than that of fiber length. Micronaire reading has no effect on yarn elongation.

In practice, it is difficult to separate the effect of fineness from the effects of other fiber properties, because fineness is associated with variety, length, and maturity. An example of the effect of Micronaire reading on neps in the card web and on the properties of a medium and a fine number warp-twist singles yarn is shown in table 3. Neps decrease rapidly and yarn strength decreases slightly with increased Micronaire reading. Yarn uniformity decreases slightly with either extra-fine or extra-coarse Micronaire reading. These effects cause the textile industry to favor fine-fiber cottons for end

Table 3. — Effect of Micronaire reading on neps and yarn quality

Property	Micronaire reading			
	3.9	4.5	5.0	5.5
Neps/100 sq. in.	20	10	9	6
Yarn Strength:				
20/1 (30 tex) -- CSP --	2361	2298	2327	2290
40/1 (15 tex) -- CSP --	1993	1985	1911	1887
Yarn Uniformity:				
20/1 -- % CV --	22.6	20.9	21.7	22.3
40/1 -- % CV --	25.0	23.3	24.3	25.5
Yarn Grade:				
20/1 --	C+	B	B	B
40/1 --	C+	B	B	B

products that require fine yarns and high product strength and coarse-fiber cotton for products that are dyed light colors.

Next to length, Micronaire is the major determinant of many textile machine processing variables. It controls carding rate because of its relationship to nep formation; the finer the fiber, the slower the carding rate. Micronaire affects roving and yarn twists required to attain maximum processing efficiency and minimum yarn breakage during spinning. Yarns made from fine-fiber cottons can be spun at higher production rates than those from coarse cottons.

This is an oversimplification of the more complex findings described in published research (7, 8, 15, 35). The textile industry is using these results as a guide in blending cottons of different fineness to achieve improved-quality consumer products.

Fiber Strength

Fiber strength directly affects yarn strength but has little or no effect on the efficiency of textile cleaning,

carding, and prespinning processes. Fiber strength does not appear to affect the draftability of cottons at different spinning drafts or the twist required to attain maximum yarn strength.

Research confirms the general knowledge that stronger cotton fibers produce stronger yarns (2, 3, 4, 32). For example, cotton with a tensile strength of 99,000 pounds per square inch consistently spins into stronger yarns than cotton with a tensile strength of 82,000 pounds per square inch. The twist-strength curves are similar. At lowest twist, yarns spun from the high-strength cotton averaged from 35 to 40 percent stronger than yarns from the weak cotton. As yarn twist increases, the difference in yarn strength becomes progressively less, until at the highest twist the yarn spun from the high-strength cotton averages 12 to 20 percent stronger than yarns from the weak cotton.

How fiber strength affects spinning performance, particularly at higher spindle speeds, is shown in figure 3. In general, however, spindle speed and yarn twist have more influence on yarn breakage than does fiber strength.

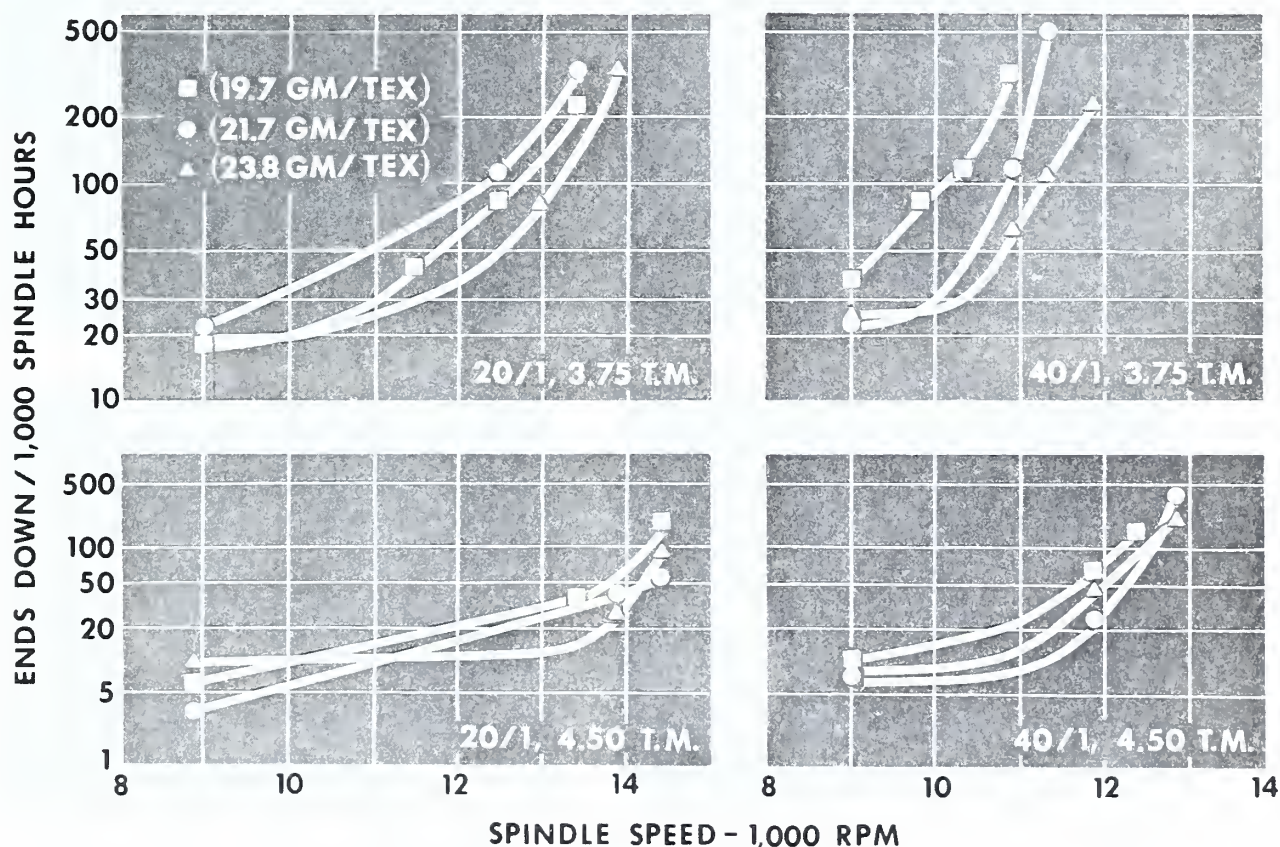


Figure 3. Effect of fiber strength on spinning performance.

Fiber Elongation

Fiber elongation closely correlates with yarn elongation; the degree of correlation is influenced by yarn twist, yarn number, and fiber length (11, 17). Fiber elongation has no major effect on textile processing before spinning (36) but does slightly affect end breakage during spinning (36). For medium-staple cottons, the greater the elongation, the lower the rate of end breakage. Generally, an increase in elongation from 6 to 10 percent makes possible a spindle

speed increase of about 1,000 revolutions per minute for medium-number yarns (fig. 4).

The effect of fiber elongation on fabric elongation is more complex, as shown in table 4. Higher elongation fibers convert into higher elongation gray fabrics, but as the fabrics undergo finishing, there is a change in warp and filling elongation that largely levels out the influence of fiber elongation (18).

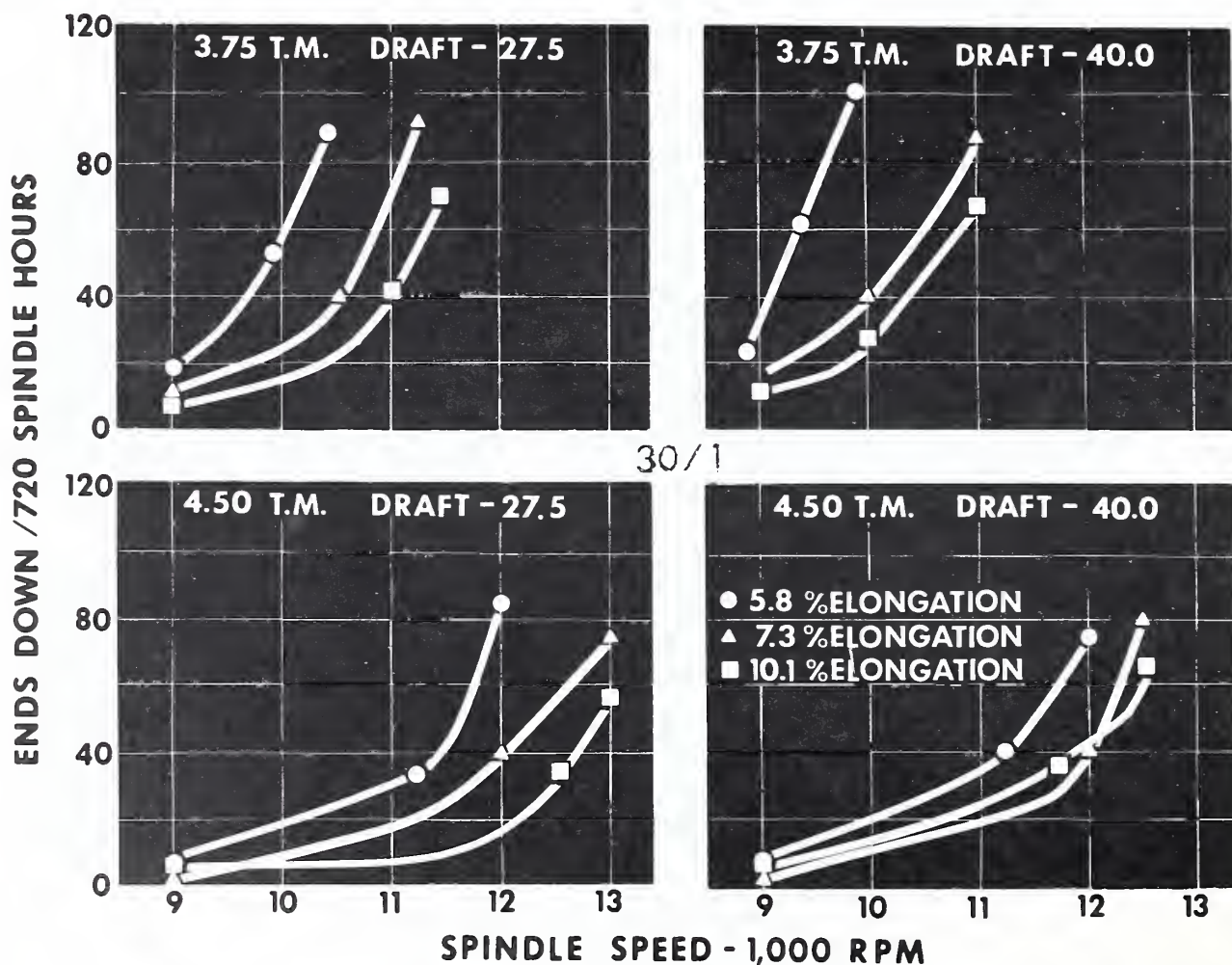


Figure 4. Effect of fiber elongation on spinning performance.

Table 4. — Effect of fiber elongation on elongation of gray and finished fabrics

Fiber elongation	Elongation					
	Gray fabrics		Bleached fabrics		Bleached, mercerized, and dyed fabrics	
	Warp	Filling	Warp	Filling	Warp	Filling
Percent	Percent		Percent		Percent	
7.1	17.3	7.6	9.8	11.2	7.2	20.5
8.5	18.0	8.6	10.0	12.2	7.0	22.8
10.0	19.3	8.8	10.3	12.4	7.1	21.1
12.3	20.4	9.6	11.0	13.6	7.7	22.9

Investigation of fiber elongation is a relatively new field, and additional research is in progress to clarify the contribution of this fiber property to the properties of yarns and fabrics.

PROCESSING RESEARCH

The rapid increase in labor and equipment costs and in interindustry and intraindustry competition has led cotton mills to seek short-cut processing systems, higher machine speeds, and increased production rates. These changes have caused greater stresses on fibers and yarns, resulting in an urgent need for improved processing technology. SRRL scientists are striving to develop basic information that will enable better techniques for blending, carding, drafting, spinning, and other textile processes.

Drafting

One of the oldest and most difficult problems of the textile industry is that of determining the allocation of drafts between processes to obtain maximum yarn uniformity and strength.

Research has been reported that provides guides for selecting the best drafts for short-, medium-, and long-staple cottons (19, 20, 21). The effect of different draft allocations on yarn properties is indicated in table 5. Selection of the optimum draft contributes substantially to strength and uniformity. As much as a 20 percent difference results from changes in draft allocations.

Table 5. — Effect of draft allocations on yarn properties

Type of cotton and draft allocation	Yarn number skein strength	Elongation at break	Uniformity Uster
	Pounds	Percent	% CV
Short-staple cotton, 10/1 (59 tex) yarn:			
Good - - -	2,646	9.60	12.8
Poor - - -	2,311	8.60	14.1
Medium staple cotton, 30/1 (20 tex) yarn:			
Good - - -	2,205	5.98	19.4
Poor - - -	1,874	6.75	23.1
Long staple cotton, 60/1 (10 tex) yarn:			
Good	1,881	7.19	19.2
Poor	1,562	6.59	20.9

Fiber Hooks

Installations of automated textile processing systems, the elimination of a number of prespinning processes, and higher processing speeds have intensified interest in cotton fiber orientation, configuration, and number and direction of fiber hooks in slivers and rovings. Hooks are simply the U-shaped or folded-back parts of the fibers.

High-speed carding and card production rates influence the formation of fiber hooks (24). Figure 5 shows the relationship between cylinder speed and minority and majority hooks. The results explain in part the puzzling phenomenon that spinning end breakage decreases with higher carding rates.

The direction in which the sliver or roving is drafted in the next machine has a significant effect on hook removal, with the hooks being more easily removed when drafted in the trailing position. Minimum yarn breakage at spinning is obtained by drafting with most of the hooks trailing at first and second drawing, leading at roving, and trailing at spinning. The amount of the fiber hooks entering the spinning frame becomes critical when some of the preparatory processes are eliminated (22, 23, 25).

The effect of hooked ends on end breakage and spindle speed is shown in figure 6. A significant increase in spindle speed can be achieved by drafting at the drawing, roving, and spinning processes in a direction to obtain maximum hook removal (26).

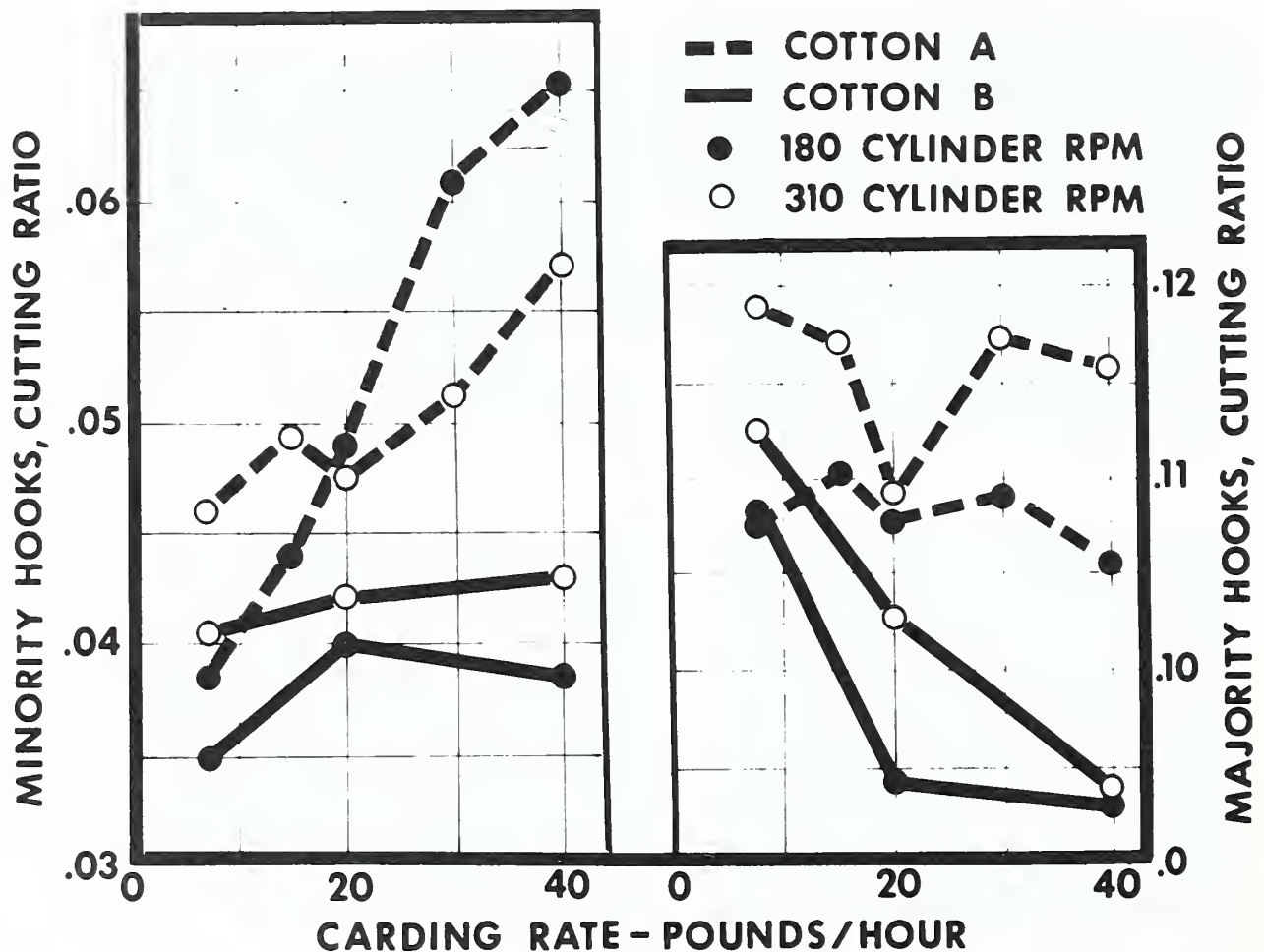


Figure 5. Effect of carding rate on fiber hooks.

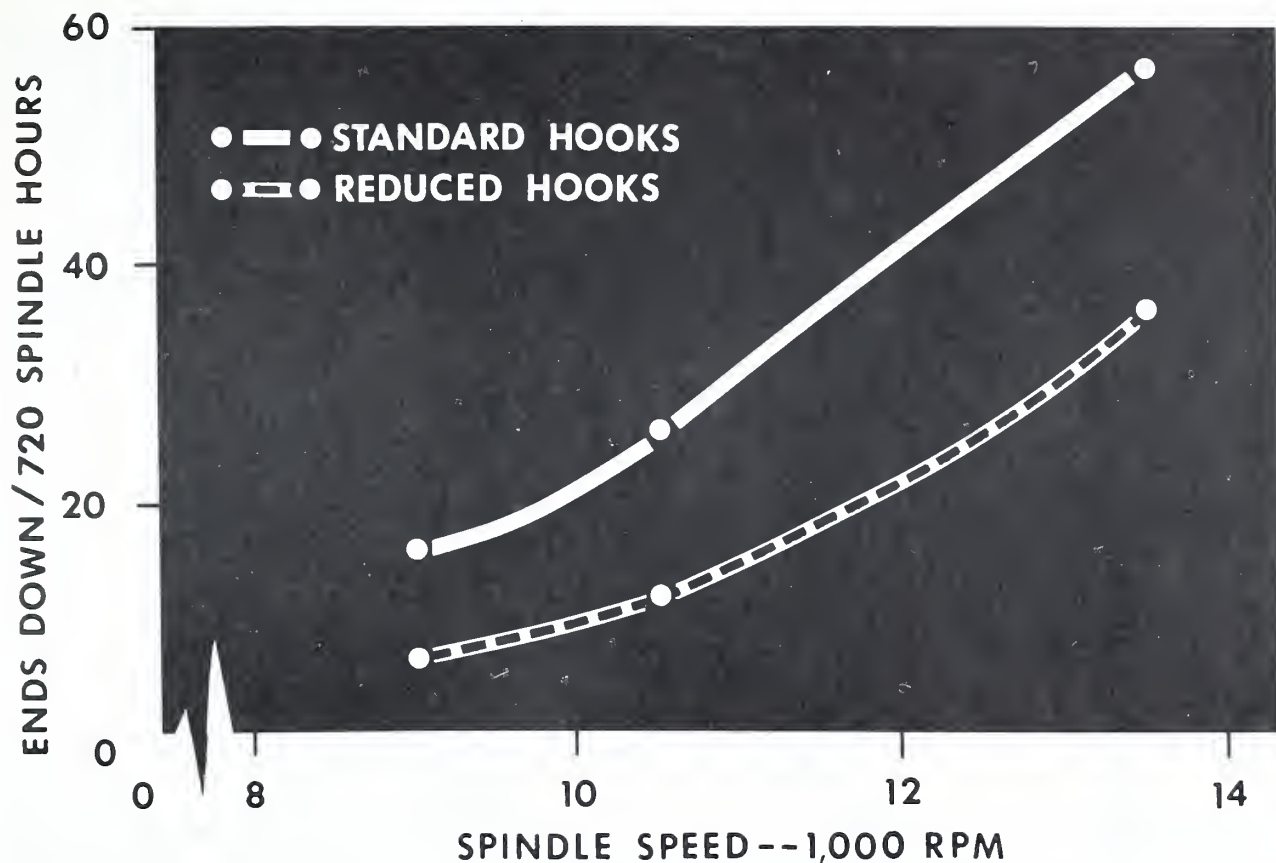


Figure 6. Effect of fiber hooks on spinning performance.

Spinning

The spinning efficiency of cotton, normally judged by end breakage rate during spinning, is of prime importance because of its significant effect on textile production costs and product quality. Many investigations have considered the effect of individual fiber properties on spinning efficiency (1, 34) and the effect of machine variables (5, 6, 14) and of combinations of fiber properties and machine variables (9, 12, 16, 28, 32, 33, 35, 36).

Investigations were conducted to determine the relative contribution of cotton fiber bundle strength, fiber length distribution, Micronaire reading, and spinning variables (spindle speed, yarn number, and twist) to processing performance and yarn properties. It was determined that:

(1) Processing efficiency and product quality before spinning were not appreciably affected by a normal range of Micronaire, fiber strength and short fiber content. Extremes in these properties tended to produce slightly more uneven sliver and roving and more neps at carding, except for coarse cottons.

(2) Fiber strength had no appreciable effect upon yarn evenness and appearance and was linearly correlated with yarn strength.

(3) High short fiber content had a detrimental effect upon both spinning performance and yarn quality, and this effect was greatest in fine yarns and low twists.

(4) It was more important to closely control fiber length distribution in a cotton mix than to control strength or Micronaire, within practical ranges.

(5) Yarn number, twist, and spindle speed had a greater effect upon spinning performance than fiber properties had, within the range of properties evaluated.

Knowledge of the relative influence of strength, Micronaire reading, and fiber length distribution contributes to scientific selection of cotton for desired levels of textile processing performance and product quality.

End Breakage

A short spinning test has been developed to aid in evaluating the relative spinning performance from comparatively small quantities of cotton (10). Researchers found that if ends down data are recorded each 15 minutes, a 3-hour run on a 240-spindle frame would allow the end breakage rate to be determined within ± 30 percent at the 95 percent confidence level. Despite these wide tolerances, the procedure furnishes useful discrimination among cottons. Lower and upper limits of 20 and

150 end breakages per 1000 spindle hours are used. Below 20 end breaks does not furnish enough breakages or "events" for statistical reliability, whereas above 150 breaks represents an impractical counting level.

The spinning performance of two cottons measured by the 720-spindle hour method is shown in figure 7. Cotton A is superior to Cotton B because it can be spun at higher speeds with less end breakage.

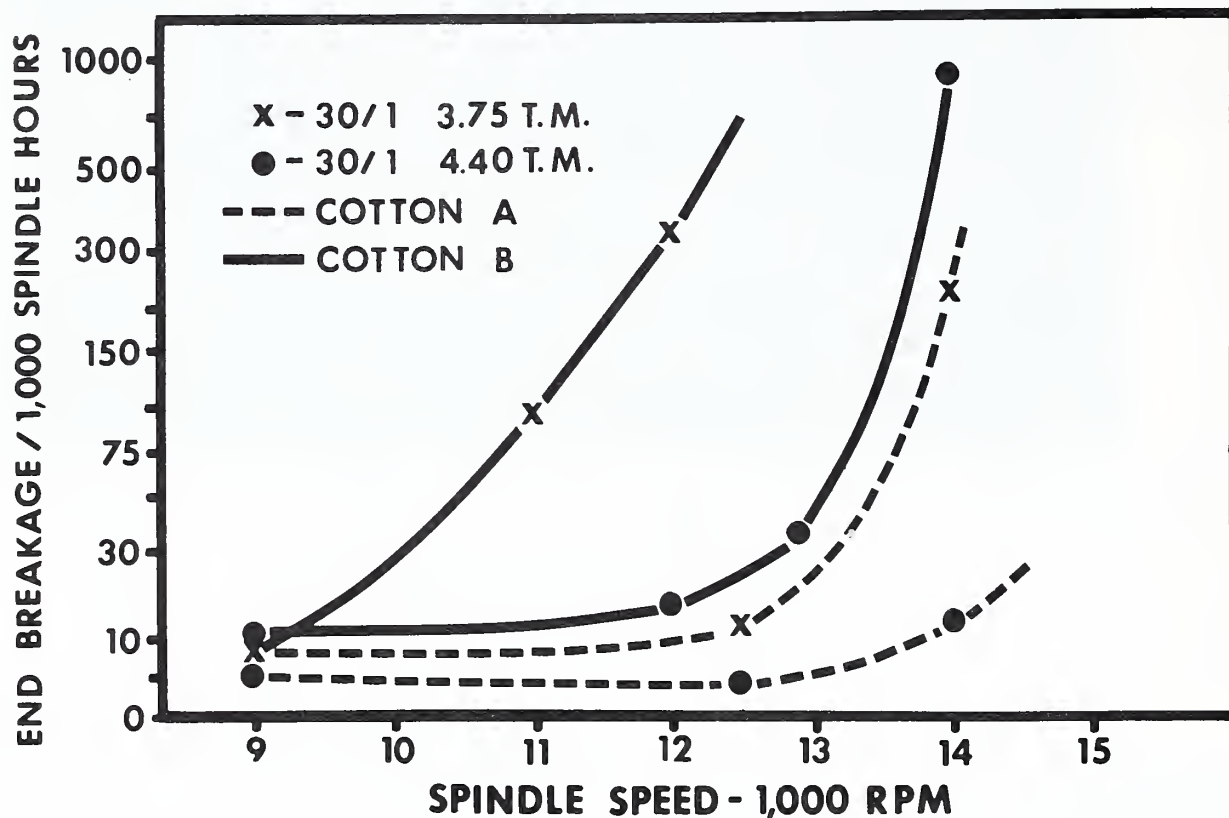


Figure 7. Spinning performance measured by 720-Spindle Hour Method.

DISCOUNT COTTON RESEARCH

"Discount" cotton is defined as cotton that can be purchased in the United States at a discount from the price paid for 1-inch staple length, Middling grade, 3.5 to 4.9 Micronaire reading cotton. The utilization of cottons outside of the 3.5 to 4.9 Micronaire range is a problem in the cotton industry. Some medium-low and medium-high Micronaire cotton is blended with average Micronaire, but there is little demand for the 3.0 and lower Micronaire except for use in low-quality and specialty products where increased waste and neps can be offset by price discounts for the cotton. Cotton of 5.0 and higher Micronaire produces fabrics that are lower in strength and uniformity but are relatively nep free and accept most dyes readily.

Micronaire discounts for 1969 were as much as 390 points (\$19.50 per bale) for the extra-low Micronaire cotton and 135 points (\$6.75 per bale) for the extra-high Micronaire. If extra-low and extra-high Micronaire could be blended and processed into products of quality equal to those from average Micronaire cotton, substantial savings to the mills would result.

A comprehensive study has just been completed with 15/16- and 1-inch cotton, using seven grades of cotton and five values of Micronaire blended in various proportions and by various methods. Time and space do not permit presenting all of the results; therefore, only the most important findings for the 1-inch cotton will be discussed. The grade combinations used are shown in figure 8. Grade II was the lowest in price and Grade III was the highest.

Grade Combination

Grade And Percent

I	SLM white _____	50 %
	SLM lt. spot _____	50 %
II	SLM white _____	50 %
	LM lt. spot _____	25 %
	LM spot _____	25 %
III	M white _____	50 %
	M lt. spot _____	25 %
	M spot _____	25 %

Figure 8. Grade blend ratios.

Figure 9 presents four of the Micronaire blends investigated. Lot A was the control and Lots B, C, and D are typical blends.

The cottons were blended by conventional hopper weigh-pan methods and by draw-frame methods. Five carding speeds and two replications were included. The

1-inch cotton was spun into 20/1 yarn at 11,000 revolutions per minute spindle speed and 4.0 twist multiplier. The 15/16-inch cotton was spun into 12/1 yarn at 9,000 r.p.m. spindle speed and 4.0 T.M.

Figures 10, 11, 12, 13, and 14 summarize the results:

Lot	Micronaire And Percent		
A	4.2—100%		
B	3.2 — 25%	4.2 — 50%	5.2 — 25%
C	2.8 — 50%	5.4 — 50%	
D	3.2 — 50%	5.1 — 50%	

Figure 9. Micronaire blend ratios.

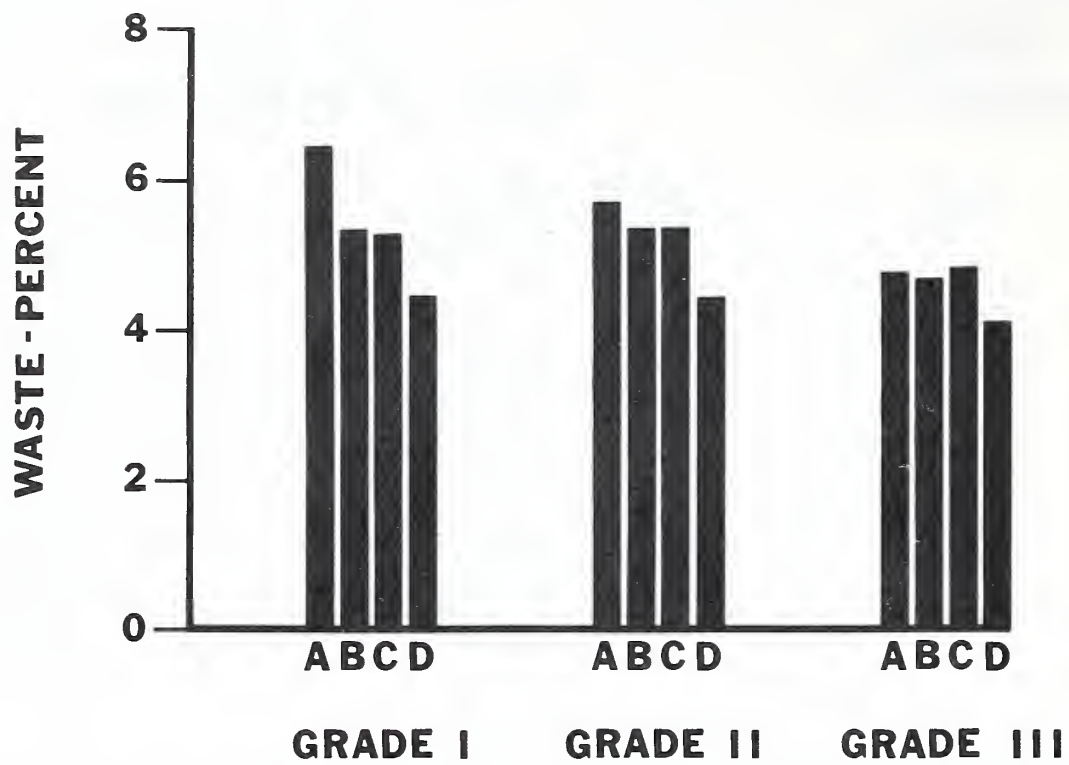


Figure 10. Picker & card waste.

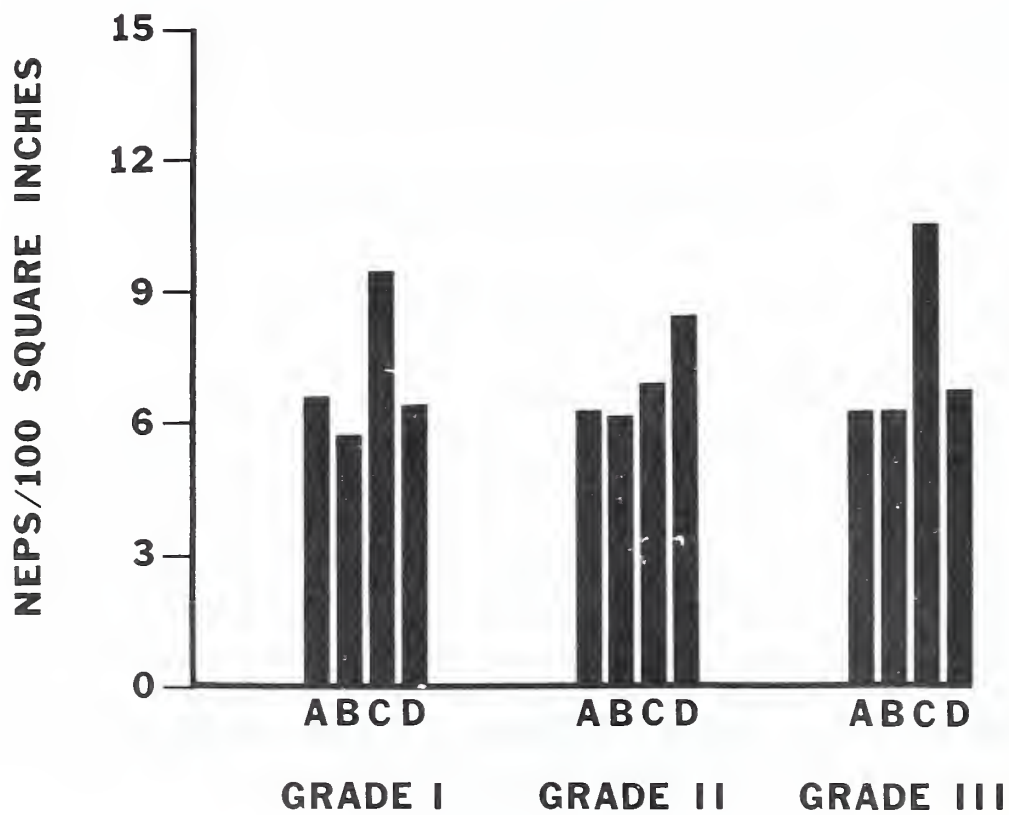


Figure 11. Card neps.

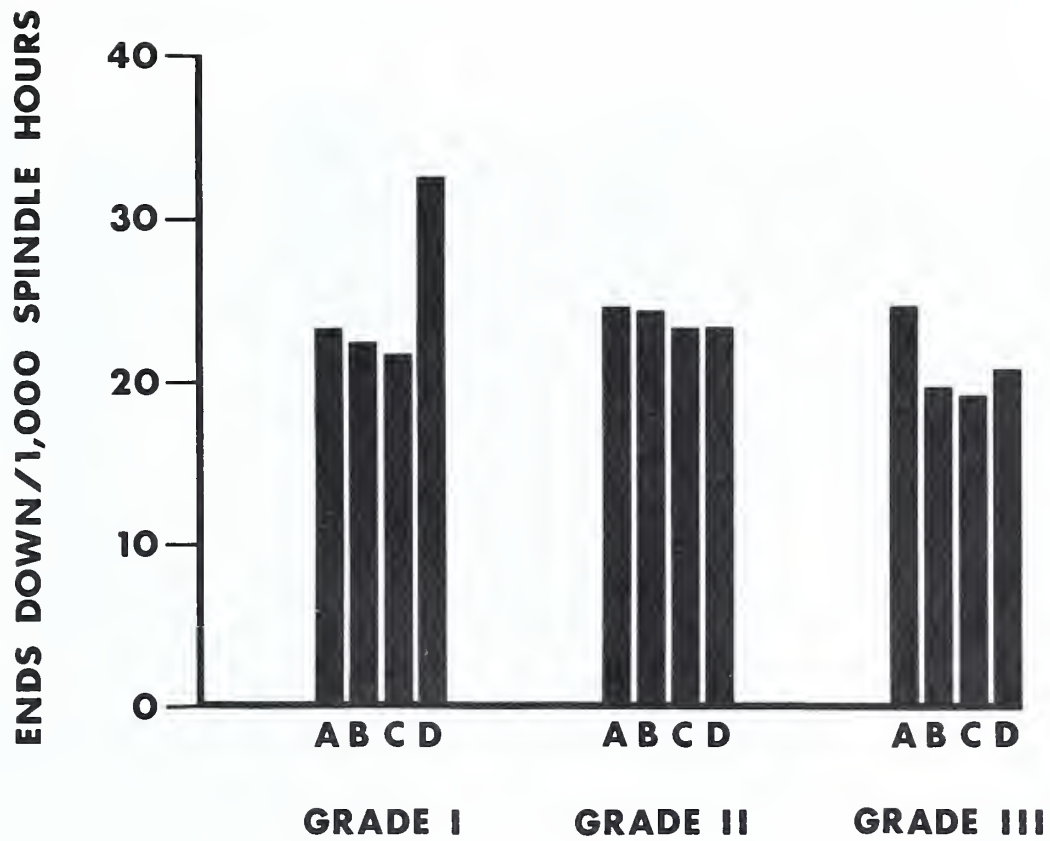


Figure 12. Spinning efficiency.

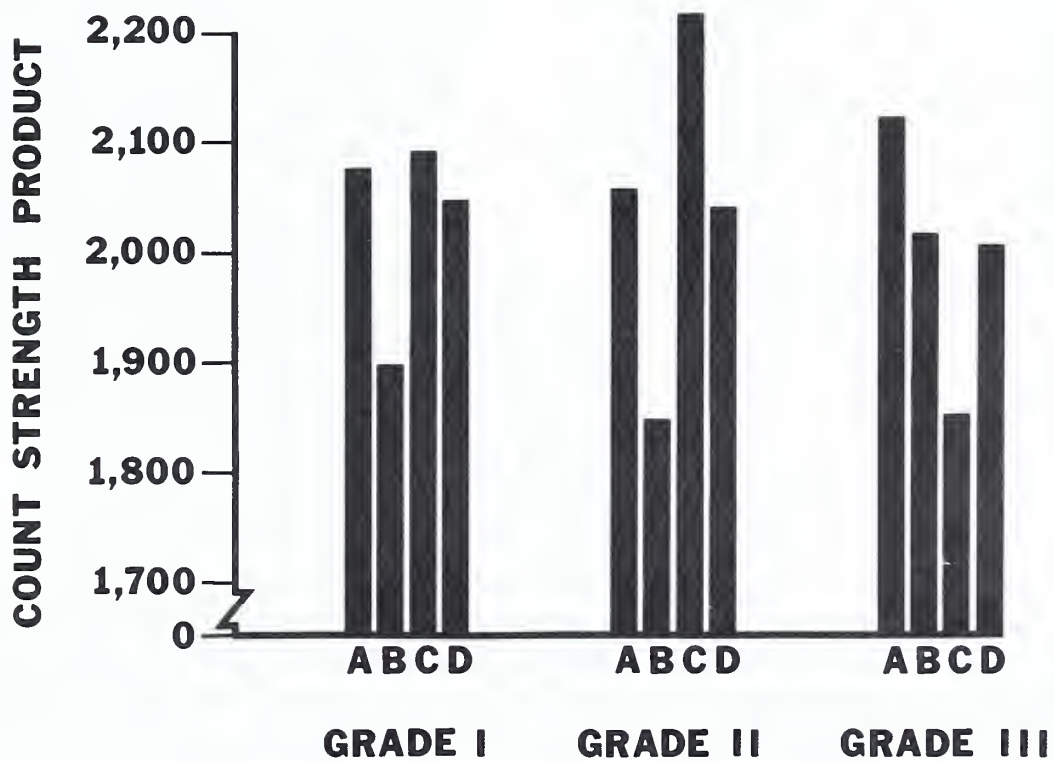


Figure 13. Yarn strength.

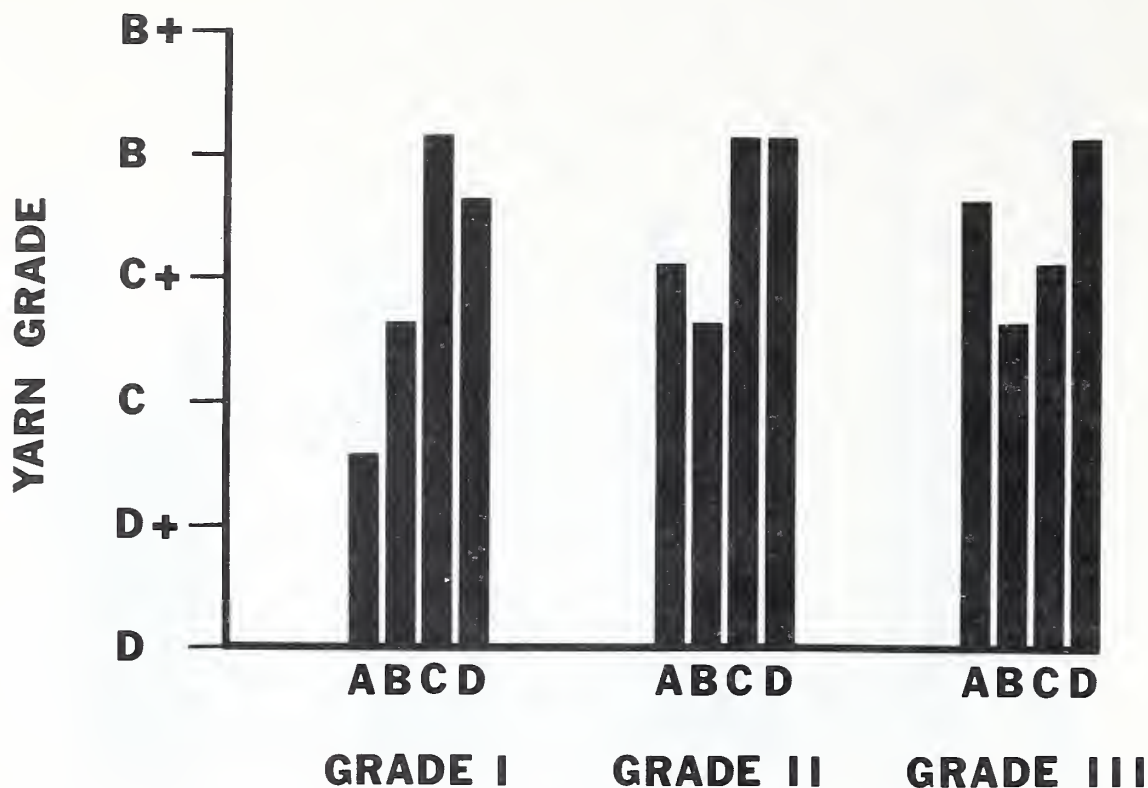


Figure 14. Yarn appearance grade.

The study showed no significant differences among mixes; therefore, a logical choice would be to use the cheapest grade combination, Grade II, which would result in a saving of 235 points (\$11.75) over the use of Grade III.

There was no consistent pattern wherein one Micronaire blend was better or worse than the others. This indicates that blends of various combinations of Micronaire are feasible and that the resulting yarns compare favorably with yarns spun from average Micronaire cotton. Blends of the extremes in Micronaire to give an average Micronaire reading of 3.8 to 4.2 appear practical for many products and would save the most money.

Yarn quality was slightly higher and processing cost was lower with the hopper-feeder method of blending than with the draw-frame method.

The yarns made from the Micronaire blends are being woven into nine different types of fabrics. The results of this study will be available the latter part of 1971.

PRODUCT DEVELOPMENT RESEARCH

Consumers of textile products have become affluent and sophisticated. They are demanding products with improved performance characteristics such as soil resistance, durable press, bright colors, and comfort styling. Research at SRRL includes product development.

Seersucker Fabric

A large potential market in the United States for cotton is that of men's and boys' dress suits and trousers. The use of cotton in this field is handicapped because cotton lacks the resilient characteristics of wool and of synthetic blend fabrics. One of the former big uses of cotton was in seersucker suits, but the high cost of frequent commercial laundering resulted in the loss of this market.

SRRL research has created an improved seersucker fabric adaptable for the entire family. Treated with durable press resins and made into men's suits and ladies' and children's apparel (fig. 15), the garments can be laundered repeatedly in a home laundry and worn without ironing. It is expected that these new, durable press seersuckers will become popular in warm climates.

Durable Press Fabric

The most exciting consumer product in recent years is durable press apparel, with a potential annual market of two million bales cotton equivalent. Today's consumer demands apparel and household fabrics that can be laundered at home and require no ironing. Apparel must be crease resistant, and yet the desired creases must be retained in trousers, jackets, shirts, and similar garments.



Figure 15. Durable press seersucker apparel.

A five-year study is in progress with the objective of providing the textile industry with guidelines for selecting the optimum fabric for any durable press end product. Fabric weights from about 3.5 to 12 ounces per square yard are being investigated.

Preliminary results have shown that certain fabric parameters affect durable press performance. Some weaves are more durable than others, single yarns wear better than equivalent plied yarns, coarse yarns wear better than fine yarns in equivalent fabric constructions, and yarn

twist has little effect (fig. 16). The research is continuing on a broadened scale in an effort to ascertain if there is a relationship between optimum fabric structure and type of chemical durable press treatment.

Research is gradually revealing the contributions of fiber properties and machine variables, individually and in combination, to textile processing efficiency and product quality. The findings are aiding the textile industry to deliver better quality products at lower prices to meet consumer demands.

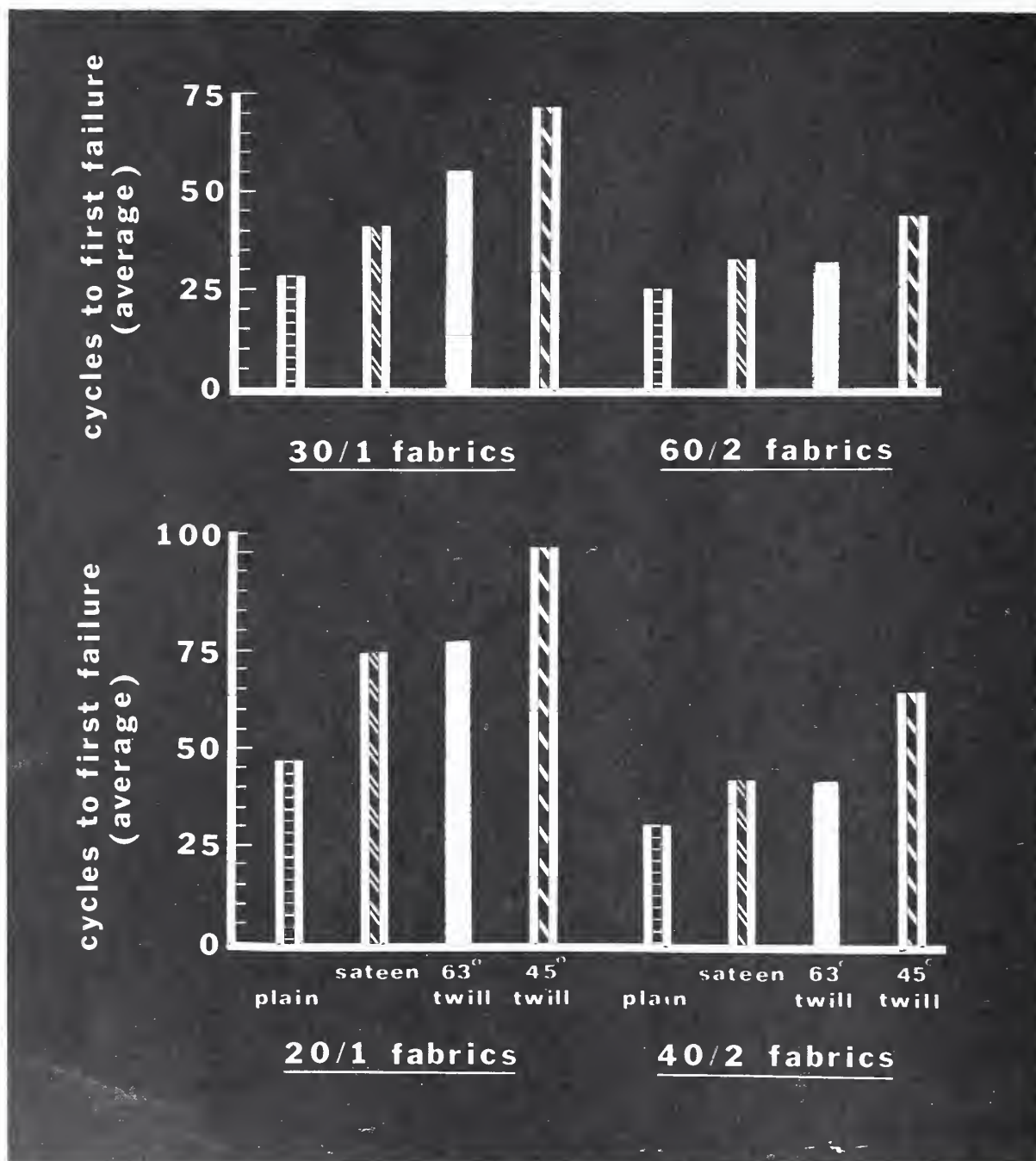


Figure 16. Performance of durable press fabrics.

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